Final Report submitted to NOAA's Human Dimensions of Global Change Research (HDGCR) Program

Project Title
Assessing Climate Applications Research and Implementation Projects

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NOAA Grant Number (where appropriate)

Time period covered
2001-2003

I. Preliminary Materials
A. Project Abstract (Text Limit: one page)
The science of seasonal climate forecasting has advanced significantly since the 1980s, and with it grew the efforts to apply this knowledge for societal benefit. These efforts were initiated by a range of scientific disciplines, government agencies, non-governmental organizations, and private companies. They were widely spread over the globe and focused on a variety of sectors. The multiple origins of the work on climate applications has generally given rise to loose networks of researchers, intermediary organizations, and users of forecasts, often based on disciplinary or regional interests, who interact occasionally through meetings, projects, and a shared body of literature. Climate applications has not yet developed into a cohesive field or community with dedicated meetings and journals, and shared priorities and approaches. The goal of this study is to identify trends in publications related to application of climate forecast advances. We approached this task by building a searchable, multi-criteria database of publications concerning climate applications. This database is accessible online through the NOAA OGP and the IRI at:
http://iri.columbia.edu/outreach/climatesociety

B. Objective of Research Project (Text Limit: one paragraph)

The broad objectives of this study include:

- Inform the community on previous work.
- Enhance collaboration within the community.
- Serve as an accessible source for storing future research results.
- Identify the patterns in knowledge generation, including strengths and weaknesses, and potential directions for future research.

C. Approach (including methodological framework, models used, theory tested) (Text Limit: one page)

Data collection

Identifying publications on forecast applications is not straight forward. First, there are only a few keywords that can separate publications related to the science of climate forecasting from those related to applications of forecasts. Any keyword based search therefore invariably yields a lot more papers on climate forecasting than on the application of such information, often by a factor of ten to one. Second, we chose to include "gray", or non-peer-reviewed, publications—such as books, reports, and periodicals—which are generally poorly catalogued. We therefore employed a variety of search strategies and tools to identify these publications, including searches of general abstract and reference databases, specialized bibliographies, reference lists at the end of applications-related publications, and cited literature searches. See Appendix I for details on the primary sources and the search strategies we used.

Using these search strategies, we identified and compiled 383 publications related to the applications of seasonal climate forecasts, 291 of which were available as full text. Whereas it was generally easy to decide which publications relate to forecast applications, inevitably the decision whether to include or exclude certain publications was subjective in some cases. We believe that we have identified almost all the English-language journal articles that have been published on applications, as we seldom now come across articles that are not in the database. Our coverage of gray literature is considerable, but probably far from complete. The current database also likely under-represents publications and research from non-English speaking regions of the world.

Publication information

For each of the publications we collected the standard citation information about the publication. In addition, we collected (where possible) other information about the publications, including:

- The sector, human activity, or natural system where the applications activity took place. We initially used the list of sectors from the contribution of Working Group II to the Third Assessment Report of the IPCC (McCarthy et al. 2001), but found that we needed to refine and expand it to fit the content of the applications publications.

- The region where the applications activity took place. Here again we used the list from IPCC (McCarthy et al. 2001), with some minor changes.
- The country affiliations of the authors, as suggested by their addresses (we found this information for 352 of the publications).
- The funding for the work mentioned in the publication. These generally involved looking in the publication itself, usually in the acknowledgements section or as a footnote to the author names (we found this information for 308 of the publications).

The number and type of applications publications in our database.

Category	Publication Types	Number
Journal Articles	Peer-reviewed journal articles	198
Reports	Project and workshop reports, report sections	77
Miscellaneous	Newsletter and magazine articles, letters to the editor, editorials, theses, journal conference abstracts	62
Books	Book, edited books, book chapters	46

List of sectors, human activities, or natural systems that we used to classify the publications.

Abbreviation	Sector	Examples of Topics Covered
Ag	Agriculture and food security	Crops, livestock, pests, crop modeling, land use, land degradation, food security, famine, famine early warning, viticulture, agricultural markets, crop and animal diseases
Water	Water resources	Streamflow, lake inflows, dam management, flood management, water quality, hydroelectricity, irrigation, water allocations, water markets, runoff
Socio	Socioeconomic systems	Multi-sectoral, economy-wide, livelihoods, development
Met	Meteorological services	National weather services, climate forecast producers, climate forecast research programs
Policy	Policy and institutions	General policies related to coping with climate variability and using forecasts, drought policy, institutional relations, institutional capacity, studies of institutions engaged in applications
Energy	Human settlements, energy and industry	Heating, cooling, infrastructure, urban planning, transportation
Other	Other	Education, culture
Insur	Insurance and financial services	Crop and hazard insurance, insurance payouts, weather derivatives

Hazard	Natural hazards management	Disaster mitigation and response, policy frameworks, damages
Fish	Fisheries and aquatic ecosystems	Fish, fisheries, corals, marine birds and mammals, algae blooms, freshwater fisheries, natural resource management, evolution, ecology, tidal zones
Media	Media	Print and broadcast media, reporting, internet
Forest	Forestry and terrestrial ecosystems	Flora, fauna, logging, forest fires, NDVI, natural resource management, evolution, ecology
Health	Human health	Epidemics, vector and disease dynamics, disease forecasting, disease early warning systems, water and air quality

List of regions we used to classify the publications.

Region
Africa
Asia
Europe
Latin America and the Caribbean
North America
Oceania and the Pacific Islands
Oceans
Global or Cross-Regional

D. Description of any matching funds used for this project. (Text Limit: one paragraph)

Extensive in-kind contribution by the IRI was provided in the form of salary contribution of Tahl Kestin, computer support by staff and continues through site maintenance.

II. Interactions

A. Description of interactions with decision-makers who were either impacted or consulted as part of the study; include a list of the decision makers and the nature of the interaction; be explicit about collaborating local institutions. (Text Limit: half page)

Not Applicable

B. Description of interactions with climate forecasting community (i.e., coordination with NOAA climate forecasting divisions, the International Research Institute for climate prediction (IRI), regional or local climate forecasting entities, etc.) (Text Limit: half page)
This study was conducted in collaboration with the IRI.

C. Coordination with other projects of the NOAA Climate and Societal Interactions Division (i.e., other HDGCR, Research Applications, or Regional Integrated Sciences and Assessments projects) (Text Limit: half page)
The project design and format for website was developed in collaboration with the NOAA Office of Global Programs.

III. Accomplishments
Below we summarize results:

Patterns in Applications Research
Trends over time
The annual number of publications from 1973 (the year of the earliest publication found) to 2002 is shown in the below figure 1. This figure, we speculate, reveals four phases in the development of the field of seasonal forecast applications:

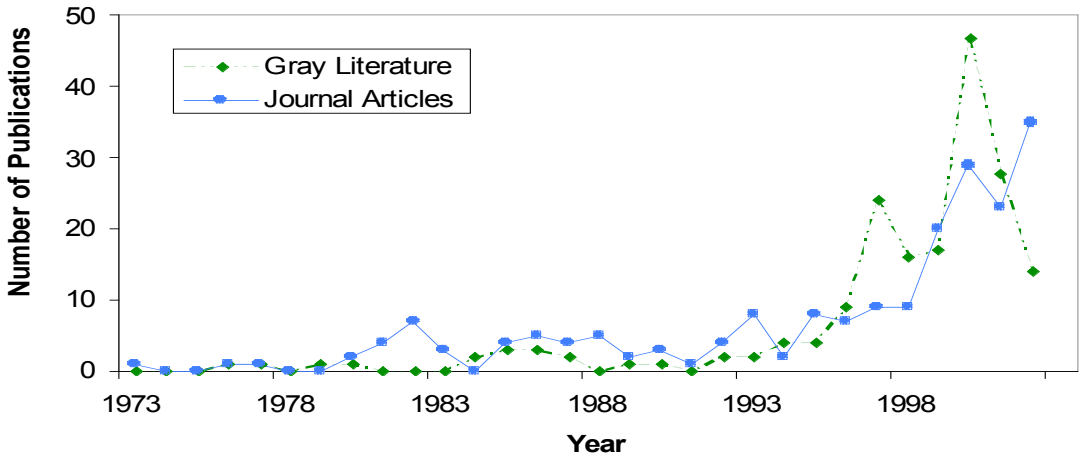
1. *Increased interest in climate variability (early 1970s–early 1980s):* The widely publicized occurrence of climate extremes since about 1968 has led to increasing interest in climate variability and its impacts (Lamb 1981).

2. *Exploring the potential of climate prediction (early 1980s–late1980s):* The US National Climate Program (established in 1978) and Climate Dynamics Program (established in 1974) fostered efforts to predict climate variations, understand their impacts on society, and improve the way society responds to them (Lamb 1981, 2002). The spike in journal articles in 1982 is primarily a result of a special issue of the *Journal of Applied Meteorology* (volume 21, issue 4) on the economic value of weather and climate forecasts.

3. *ENSO forecasting and global applications initiatives (late 1980s–late 1990s):* Intense efforts to study ENSO and its socio-economic impacts during the 1980s (such as through the TOGA program) resulted by the late 1980s in ENSO-based regional climate forecasts being issued routinely around the world. Interest in the potential of these forecasts to mitigate the socio-economic impacts of ENSO led to the creation of several initiatives to advance applications—such as the NOAA Office of Global Programs (OGP) Pilot Program for the Application of Climate Forecasts in the US (Buizer 1997), the National Climate Variability Program in Australia (White 2000), and the International Research Institute for Climate Prediction (NOAA 1996).

4. *Seasonal climate forecasting comes of age (1999 to Present):* The 1997–98 El Niño marks a turning point in the global awareness of El Niño (Glantz 2000) both because of its magnitude and because it was the first time that climate forecasts for the effects of the event were available widely, publicly, and well in advance. During the event, there was a flurry of activity to help users around the world respond to the forecasts (for example, NOAA 2000). After the event, there was increased interest from the public, researchers, governments, and funding agencies to further explore the potential of seasonal climate forecasts. The 1997-98 event was also a natural experiment to examine how forecasts had actually been used (Glantz 2001).

The history of climate forecast applications in recent years has been intertwined with advances in our understanding of ENSO and its impacts (NOAA, 1996). This is certainly true from the late 1980s onwards, when ENSO forecasts became available. However, before that, the work on applications developed in parallel, but was not directly linked to the predictability of ENSO. So there is no causal link between the first two phases of work on applications and the occurrence of the strong El Niño events of 1972–73 and 1982–83. The sharp decline in the number of gray literature publications in 2001 and 2002 can in part be explained by the time lag in having such materials widely available, particularly given that there are no real-time repositories for these publications. So we may not have had access to many 2001-2002 gray publications at the time of writing.



Sectors

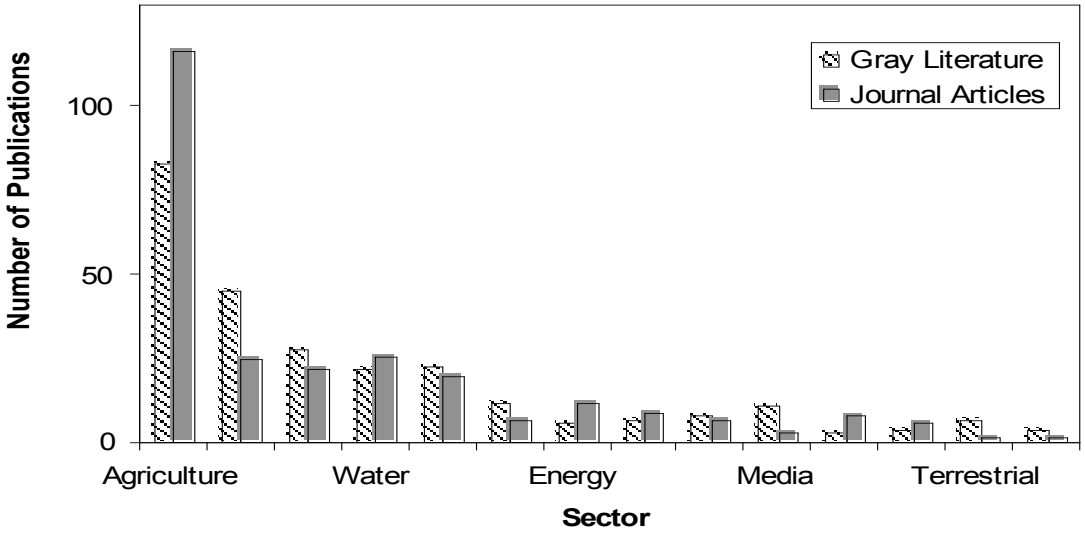
The division of publications by sector s reveals that the efforts directed towards applications of seasonal climate forecasts in different human-related activities have been uneven.

Applications in agriculture and food security have received by far the most attention of all the sectors—about four times as much as water resource management. This discrepancy is somewhat surprising, given that climate has strong direct effects on activities in both of these sectors, and that research in both fields has had long-standing collaborations with climate science.

Water resources management is not the only field where there has been a surprisingly small amount of work done on forecast applications; fisheries and health also fall into this category. The effects of climate variability on both these sectors have been known for a long time, and both have substantial resources going into furthering this understanding.

Several other sectors are frequently mentioned as having great potential for applying seasonal forecasts—for example, energy use and hydropower, insurance, natural hazard management, international trade and commerce, tourism and travel, and forestry (e.g., NOAA 1996, Stern and Easterling 2000). The below figure shows clearly that this potential has generally been unexplored.

More generally, the amount of research done on applications in different sectors may be a function of perceived relative importance of different activities, the history of disciplinary ties to climate, the fact that some sectors lend themselves more easily to experimental analysis and quantitative modeling (e.g., crop and hydrological modeling), or serendipitous overlap in those individuals who have interest in interdisciplinary approaches.



Regions

The below figure shows that there is a large disparity in the amount of work done on applications of seasonal forecasts in different regions of the world. Some of this disparity, particularly for Latin America, which has many local scientific journals (Gálvez et al. 2001), may have resulted as a result of the bias towards English-language publications in our database.

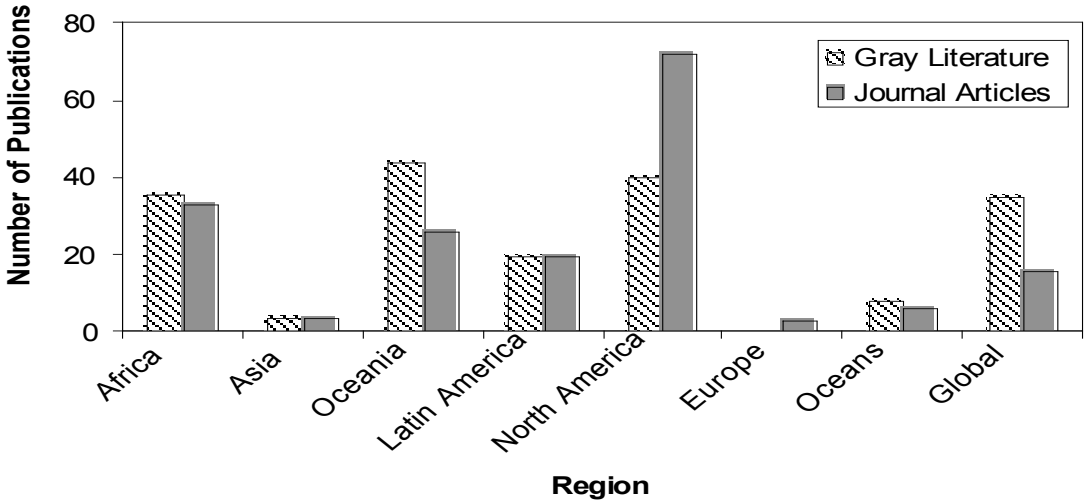
The majority of the work on applications has focused on North America—particularly the US. There are many possible reasons for greater activity in the US: the early interest in applications of forecasts (Lamb 1981), a large and well established climate and climate forecasting research community, dedicated funding incentives (such as NOAA's Pilot Applications Program and the Regional Integrated Sciences and Assessments Program), close ties between commercial activities and meteorology, and a strong influence of ENSO.

If we consider the number of publications per capita, Oceania, particularly through Australia, would have the largest regional share of activity, for many of the same reasons that we suggested for the US.

The relatively large number of publications addressing applications in Africa may reflect the interest of researchers and funding bodies in vulnerable areas. In Africa, extreme climate variability and a large population that is highly vulnerable to it have repeatedly combined with disastrous consequences—for example, the droughts in the 1970s, the famine in Ethiopia in the early 1980s, and the famine in southern Africa in the early 1990s. There has long been an interest in improving the ability of Africans to cope with climate variability. This interest combined with the reasonable climate predictability based on ENSO in the region to make seasonal climate forecasts seem like a possible solution to Africa's climate woes (e.g., Gibberd et al. 1996). As we show later, most of the work in this region was funded and carried out by external agencies.

Latin America falls somewhere in between the US and Africa. Several countries in Latin America, such as Brazil and Argentina, have a growing scientific output (Gálvez et al. 2001), as well as a long-standing interest in forecasting climate variability and its applications. We suspect that publications from these countries are under-represented in the database.

There are remarkably few publications on applications in Europe and Asia. Lack of interest in seasonal climate forecasting in Europe is partially understandable: it is not as vulnerable to seasonal climate variability as many other tropical regions of the world are, and there is relatively low skill in predicting seasonal climate variability in the region. Furthermore, climate research in Europe is dominated by issues of climate change rather than climate variability.



Journals and Disciplines

In order to estimate who is contributing to applications research and the audience they reach through their publications, we examined the journals publishing applications articles and their disciplinary affiliations. We found that the articles were both heavily concentrated in meteorology journals and very thinly spread elsewhere.

To classify journals according to disciplines, we used the subject categories assigned by the ISI (Institute for Scientific Information). The ISI classified 80% of the journals in our database; we classified the rest according to the same list of categories used by the ISI. Some of journals fitted into more than one subject category.

The 198 journal articles on forecast applications were published in 77 journals. Fifty percent of the articles were published in just the eight journals shown in Table 4.

Of the eight journals shown below, six have been classified as “meteorology and atmospheric sciences” journals by the ISI. Overall, almost 50% of the articles came from journals with this classification. The rest of the articles came from journals that were classified under 38 other subject categories—the next largest categories being “environmental sciences” and “agriculture, multidisciplinary”.

The distribution of applications articles in journals has several practical implications. On one hand, the focus on meteorology journals may explain to a

certain degree why interest in the topic of forecast applications has spread to only a limited degree to other disciplines. It also raises the question of quality control of work if social-science analysis is being reviewed primarily by physical scientists. On the other hand, the dispersion of articles in many journals makes it unlikely that people working on forecast applications will be aware of much of the other work that is occurring in their field.

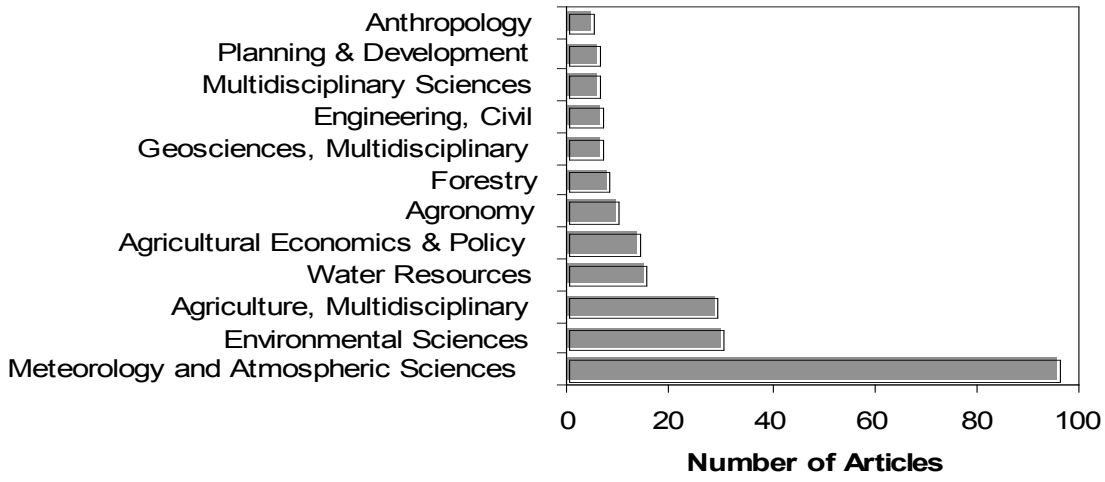
On a more general level, the disciplinary dispersion of applications articles can give us an indication of the engagement of different disciplines in applications research. The large concentration of articles in meteorology journals reflects the history of the field of forecast applications, which was defined and initiated mainly within the meteorology community (a history which led to many *a priori* assumptions being made about how people could use forecasts and how useful these forecasts will be). In contrast, only 20% of articles on the impacts of ENSO (which we have also collected in the database) have been published in meteorology journals.

The dominance of articles being published in meteorology journals is diminishing. The figure below shows that, beginning in the early 1990s, the number of articles in non-meteorology journals has grown faster than the number in meteorology journals. This result indicates that there is a growing engagement of other disciplines in work on applications research. This may also be part of a broader trend in "human dimensions" research that has become increasingly prominent since the early 1990s.

The journals that published most applications articles. The 8 journals listed in this table published 50% of all applications articles.

Rank	Journal
1	Bulletin of the American Meteorological Society
2	Agricultural Systems
3	Journal of Applied Meteorology[1]
4	Climatic Change
5	Agricultural and Forest Meteorology[2]
6	American Journal of Agricultural Economics
6	Climate Research
7	Journal of Climate

[1]Previously known as *Journal of Climate and Applied Meteorology*
[2]Previously known as *Agricultural Meteorology*



The applications community

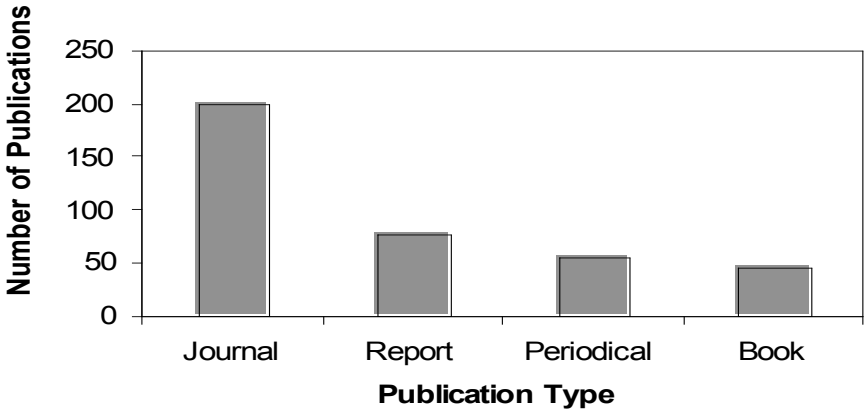
By examining the authors of the applications publications, we could estimate how many are people are working on forecasts applications, and where they are based.

From the beginning of the record to 2002, 536 individuals contributed to work on applications, 143 of them at least twice. In the last five years, 399 individuals contributed, 101 of them at least twice. The growth in the number of people contributing over time closely follows the growth in the number of articles shown in Figure 1.

Four people have contributed to the field of forecast applications for 20 years or more: Michael Glantz (who first published in this area in 1976), Peter Lamb (since 1981), and Stephen Sonka and Stanley Changnon (since 1982). Not surprisingly, these people are among those with the most publications in the field.

Authors of applications publications came from all regions of the world, but there were marked regional differences in the contributions to publications on applications. As Figure 5 (and Figure 5 alternative) shows, local authors contributed to most of the publications in Asia, Oceania, North America and Europe, but only to a small share of the publications in Africa and Latin America. Furthermore, in both Africa and Latin America, most of the publications that had local authors also had collaborators from other regions. In both these regions, the bulk of the non-local authors (whether on collaborative publications or publications without local collaborators) were based in the US. In fact, authors based in the US contributed to 67% of all the publications.

These patterns fit with the findings of Gálvez et al. (2001) on regional differences in general journal article outputs and degrees of collaboration. They attribute these differences to regional variations in the strength of the local research community and ultimately to variations in research spending.



Funding for applications research

We found information about sponsors of applications activities in about half of the publications. Overall, the publications acknowledged over 100 institutions in supporting applications work. These institutions ranged from various government agencies and departments, academic and research institutions; international governmental, non-governmental, and scientific bodies; foundations; and private industry. Almost 100 publications acknowledged the US National Oceanic and Atmospheric Administration (NOAA), and particularly the Office of Global Programs (OGP), for providing funding for the work mentioned in the publication. NOAA was the main sponsor (according to number of publications) of work in North America, Africa, Latin America, as well as of global studies. Other large sponsors of applications work included Land & Water Resources Research & Development Corporation (LWRRDC) in Australia, the Inter-American Institute for Global Change Research (IAI) in Latin America, and the National Science Foundation (NSF) in the US.

The results of this study should not be interpreted as an assessment of the use of climate forecast information, but of the published academic research covering the subject. A description of the literature on seasonal climate forecast applications is just the first step in a more challenging and important task: synthesizing what has been learnt about applications in different countries and sectors. There are many individuals and groups actively engaged in the use of climate information with little or no incentive to publish the results of their activities. A challenging, but potentially rewarding research undertaking will be an assessment of these efforts.